Exciting luminescence through irradiation with ultraviolet light and electrons

Objects of the Experiment

- Exciting luminescence through irradiation with ultraviolet light and electrons

Principles

Luminescence is the emission of light following the absorption of energy. This energy can be transmitted in the form of e.g. high-energy electrons or photons which have an energy higher than that of the emitted photons. When the excited electrons undergo internal energy transitions before re-emitting the energy from the absorption event the emitted photon has less energy than the energy absorbed. The energy difference between the absorbed and emitted photons ends up as heat.

The most familiar such effect is fluorescence, which is typically a fast process, but in which some of the original energy is dissipated so that the emitted light photons are of lower energy than those absorbed. The emission of photons fades exponentially very rapidly when excitation is switched off (*i.e.* about 10^{-8} s)

An even more specialized form of luminescence is phosphorescence, in which the excited electron undergoes intersystem crossing into a state of higher spin multiplicity, usually a triplet state. Once the energy is trapped in the triplet state, transition back to the lower singlet energy states is quantum mechanically forbidden, meaning that it happens much more slowly than other transitions. The result is a slow process of radiative transition back to the singlet state, sometimes lasting minutes or hours.

In this experiment, the luminescence of various solids following irradiation with ultraviolet light or electrons is demonstrated. These samples include yttrium vanadate doped with europium (red fluorescent), zinc silicate doped with manganese (green fluorescent) and barium magnesium aluminate doped with europium (blue fluorescent). In each case the dopand is responsible for the fluorescence visible after excitation. The samples are irradiated either by electrons emitted by an electron gun located in the luminescent tube (cathodoluminescence) or by ultra violet light emitted by a high-pressure mercury lamp (photoluminescence). That ultraviolet light is needed to get photoluminescence is tested using an ultraviolet filter which is non-transparent for visible light.

Apparatus

1 Luminescent tube	555 618
1 Stand for electron tubes	555 600
1 High voltage power supply 10 kV	521 70
1 High-pressure mercury lamp	451 15
1 Lamp socket E27 on rod	451 19
1 Universal choke 230 V, 50 Hz	451 30
1 Ultraviolet filter	469 79
1 Saddle base	300 11
1 Safety connecting lead, 25 cm, red	500 611
1 Safety connecting lead, 50 cm, red	500 621
1 Safety connecting lead, 100 cm, red	500 641
1 Safety connecting lead, 100 cm, blue	500 642
2 Safety connecting lead, 100 cm, black	500 644

Safety notes

The tube of the luminescent tube is a thin-walled, evacuated glass bulb. There is danger of implosion!

- Do not subject the tube to mechanical stresses.
- Use only safety connection leads at the connection field of the stand for electron tubes.

The high-pressure mercury lamp emits ultraviolet light. Do not look into the direct or reflected light beam!
The lamp bulb becomes very hot – greater than 100 °C!

Observe the notes contained in the instruction sheet of the luminescent tube (555 618), the stand for electron tubes (555 600) and the high-pressure mercury lamp (451 15).

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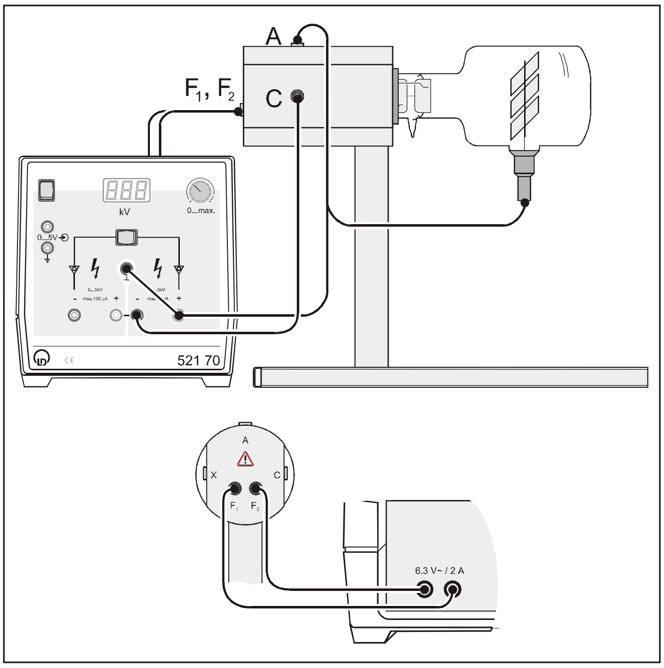

Fig. 1: Setup for observing cathodoluminescence

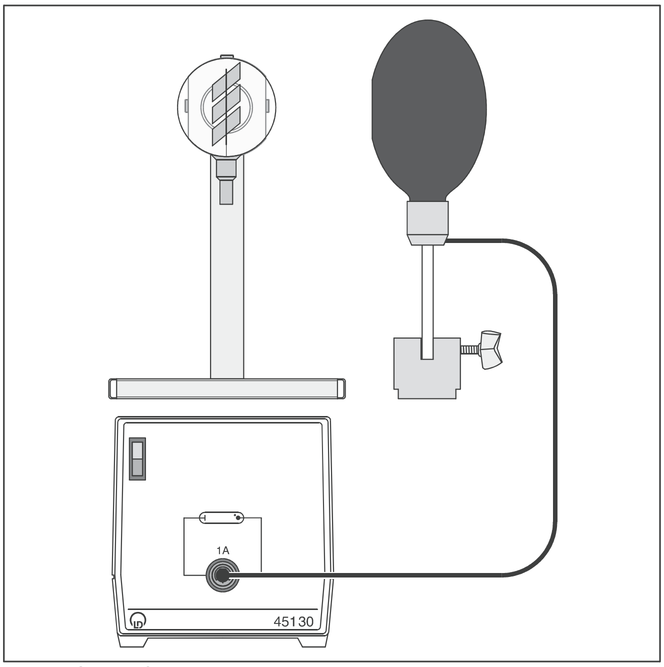

Fig. 2: Setup for observing photoluminescence

Setup

The setup of the experiment is shown in Fig. 1 and Fig. 2.

- Hold the luminescence tube horizontally, and turn it so that the two pins with the greatest distance in the pin base point downwards.
- Carefully insert the pin base in the socket of the tube stand until it stops.

Carrying out the experiment

Cathodoluminescence

- For the cathode heating connect the sockets F_1 and F_2 of the tube stand to the output on the back of the high-voltage power supply 10 kV.
- Connect the socket C of the tube stand (cathode cap of the luminescent tube) to the negative pole and the socket A (anode) to the positive pole of the high-voltage power supply 10 kV and ground the positive.
- Connect the luminescent samples to socket A.
- Switch the high-voltage power supply 10 kV on and observe the luminescent samples, without looking into the bright light of the cathode filament.
- Enhance slowly the anode voltage *U* to 4.5 kV and observe the coloured luminous phenomenon of the luminescent samples.
- Switch off high-voltage power supply and observe the afterglow of the samples.

Photoluminescence

- Connect the high-pressure mercury lamp to universal choke.
- Observe the coloured luminous phenomenon of the phosphors, without looking into the bright light of the high-pressure mercury lamp.
- Hold the ultraviolet filter into the path of rays and continue to observe the coloured luminous phenomenon.
- Switch off universal choke and observe the afterglow of the luminescent samples.

Results

Cathodoluminescence

After switching on the high-voltage power supply the luminescent samples are irradiated by the light of the cathode filament. The samples look still white, no fluorescence is visible. After enhancing the anode voltage up to approx. 0.7 kV the sample in the middle shines faint green. Going to higher voltages the green glow becomes stronger and the upper samples start glowing red. At voltages higher than 4 kV the lower samples show blue fluorescence while the other samples show strong red and blue fluorescence (see Fig. 3 left). After switching off the anode voltage no afterglow is visible.

Photoluminescence

When the samples are illuminated with white light, *i.e.* without the ultraviolet filter, all samples show bright white reflection. If one holds the ultraviolet filter in the path of the rays only the lower samples show blue fluorescence, the upper samples stay dark (see Fig 3 right). After switching off the universal choke no afterglow is visible.

Supplementary information

It is possible to recognize individual emission lines within the band spectrum using a pocket spectroscope.


Fig. 3: Cathodoluminescence (left) and photoluminescence (right)

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